European Innovation and Technology Diffusion: Evidence from Patenting Data

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Abstract:

The following paper is a progress report of a study that I am conducting on the role of patenting institutions on European technological innovation and diffusion. I am conducting this study particularly on European data since the European region has developed unique institutions and has strongly reformed its patenting regime.

The European area has developed a regional patenting system that has been evolving since the late 1970s. Major changes have been made to patenting procedures, patent rights, and patenting costs. Further changes are expected in the European region with the adoption of the *Community Patent Convention (CPC),* which will further streamline procedures and introduce new laws. The question of interest is how these new rules and institutions have affected technological activity. Technological activity is rather complex, involving firms' decisions to invest in research and development, their strategic decisions to patent, innovate, and license their innovations, among other activities. The focus of this project is on R&D and patenting decisions. This paper reports on the tentative findings on patenting decisions. Studying the effects on R&D is a work in progress.

As part of this research project, I have explored (i) the institutional details of the EPO, (ii) general trends in R&D and patenting in the EPO, (iii) previous research and policy studies, and (iv) have carried out some empirical analysis and model testing. This paper is a brief summary of the investigations into each of these areas. Exploring and explaining how the dynamics of European technological activity have shifted is very much an ongoing work.

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I. Introduction

World trading arrangements come in many forms: multilateral, bilateral, or regional. Such is the case with institutions governing innovation and technology policy. The World Intellectual Property Office (WIPO) treaties and the World Trade Organization's Trade-Related Intellectual Property Rights (TRIPS) Agreement are example of multilateral rules and regulations. WIPO also provides a multilateral procedure for obtaining patent and trademark rights. The European Patent Office (EPO) is an example of a regional patenting institution. The smaller size and scope give the European region a number of advantages. The members have similar national laws, customs, and technological capacities, making the implementation of shared agreements relatively less cumbersome. The goals and rules may be viewed as relatively less far reaching.

The purpose of this study is to determine the extent to which the regional patenting arrangement has improved European member nations' innovative capacities and access to new technology. That particular regional arrangements can have real effects is testament to the important role of institutions.

Innovations are an important source of an economy's long run level of productivity. Policy and institutions regarding intellectual property protection and rewards matter to innovative activity and to the subsequent diffusion of innovations. Cross national patenting is an important source of international technology diffusion (from country to country); it involves not only the diffusion of new products and processes but also knowledge spillovers from the information disclosed by inventors in exchange for the patent protection they receive.

In this study, I analyze the level and determinants of innovative activity in Europe. One way to gauge innovative activity is by the intensity of patenting activity. In Europe, patents are filed by both domestic residents (nationals) and foreign residents (particularly from the U.S., Canada, and Japan). Thus it is important to study factors that stimulate European innovation as well as factors that motivate foreigners to bring technologies to Europe.

The significance of this project is to better understand the productivity dynamics in Europe and to evaluate the regime for innovative activity. Innovations are occurring in various new technological fields (such as telecommunications, the internet, biotechnology, finance, and so forth). What are Europe's comparative strengths in innovation? How receptive are European policies and institutions to these underlying developments? Must European nations harmonize their technology policies as well as legal institutions governing intellectual property? Several reforms have been proposed in the region (including the *Community Patent Convention (CPC)*) to face these challenges, but there has been little formal research on the nature of innovative activity in Europe, particularly empirical work linking innovative activity to the laws, policies, and institutions governing intellectual property rights. This project exploits data on patenting by European member states to help answer these issues.

The paper is organized as follows: section II briefly describes how the European Patent Office (EPO) system works, and reviews some of the key policy issues (particularly relating to ongoing reforms and the *cost* of patenting in the EPO, which many have argued acts as a barrier to the potential use of the system for acquiring patent rights and to the diffusion of new technologies. Section III provides a theoretical model of international patenting behavior; section IV discusses the data and some sample statistics; section V contains some empirical results and tests; and section VI concludes and discusses some future extensions. This study is a work in progress; however, the main results are that patent rights are a positively significant determinant of foreign patenting. Costs are also important. Incentives matter.

II. Institutional Background and Issues

This section reviews the background institutional details of international patenting and the role that the EPO plays in this wider context.

The EPO, first of all, is not a European Community institution per se but an institution created by intergovernmental agreement in 1973. The system began in 1977 with seven members, with four more added by 1980. At present (2003), there are 20 European countries that are members. Several (particularly Eastern European, former socialist states) are waiting in the wings to join (i.e. extension countries). The EPO is a regional patenting system that provides for patent protection in these twenty member states on the basis of a single patent application and of a uniform procedure before the EPO examination authority. Once an EPO patent is granted, the rights holder must validate the patent in the individual national offices (i.e. of the member states), complying with local rules and paying local fees. A European patent then has the same legal effect as would several separate national patents in the various member states. The advantage is of a single filing; thus the EPO patent is a "bundle" of rights. However, enforcement is local. EPO patents are subject to national laws in the same way that separate national patents are. The European area is currently contemplating adoption of the Community Patent Convention (CPC). The CPC will go farther than the EPO. Instead of just a single filing and procedure before the EPO, the CPC patent will, in addition, automatically have force across member states. In other words, it will make enforcement a regional matter. Having one central procedure that is automatically binding across all member states will help rationalize the administration and lower the costs of patenting. The Community patent system will also establish a Community patent court that would introduce European-wide litigation procedures.

In any event, at present a single regional filing procedure is available to inventors who apply in member nations of the EPO. The advantages of a single EPO application are: a) language, as the application can be made in any one of the three languages (English, French, or German), but upon grant, it must be translated into the native languages of the countries designed in the application; b) a single, centralized examination; c) filing-cost savings (provided coverage is sought in at least 3 member nations). A disadvantage of the EPO application is that the applicant puts all her "eggs in one basket." If the EPO rejects the patent application, the applicant cannot then apply directly to national patent offices. While the EPO patent has effect in each of the jurisdictions designated, it is enforced individually within the national jurisdictions.

The EPO is also part of the Paris Convention and the Patent Cooperation Treaty (PCT) – that is, the EPO is treated as one member bloc. The *Paris Convention* allows inventors in member countries up to 12 months to file an application in other member countries after first filing in one member country (usually the country of origin of the inventor). The inventor thus reserves that initial filing date, for 12 months, for purposes of establishing who was first to file.

The *Patent Cooperation Treaty (PCT)* permits inventors to file a single "international" patent application in as many of the member nations they wish to designate. The PCT establishes priority, as before with the Paris Treaty, on the basis of the earliest domestic filing. The filing of a PCT application also extends the deadline for filing foreign applications in member nations to 20 months (i.e. adds 8 months to the 12 from the Paris Treaty). Some cost savings are realized by the inventor with the PCT application, for example a reduction in search costs. Eventually the inventor must file, and incur the necessary costs of, separate national patent applications in each of the designated countries within 20 months, or else forfeit patent rights in those countries. Countries that are members of *PCT II*, however, may provide a further 10 month extension, giving a total extension time of 30 months, at the end of which applicants must go to the national phase (i.e. file in the separate jurisdictions) or else forfeit patent rights.

One of the common concerns about the EPO is the cost of patenting. Compared to patenting in the U.S. or Japan, the EPO region is regarded as the most expensive place (due to the costs of translations and need for attorneys in separate jurisdictions).[1] This may deter inventors from using the EPO (and filing separate national patents instead) or from filing patents at all. Much attention had focused on the divergent levels of patent *rights* across nations, particularly on the weak level of patent rights in certain countries. Recently, however, attention has shifted to the *costs* of obtaining patent rights. The realization is that laws protecting patent rights are of little service if those rights are not affordable.

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[1] EPO applicants also face large translation burdens due to the number of states involved. Surveys by SACEPO (1995) and CIPA (1997) find that the cost of translating a 20 page patent into the eight most commonly designated EPO states to be 15,200 DM (or $8085 US) and 14,195 DM (or $7550 US) respectively. These translation costs are approximately 40% of the total patenting costs (i.e. sum of translation, attorney, and official fees).

There are of course problems with measuring patenting costs and comparing them across regions. First, surveys provide an idea of how expensive international patenting can be but none indicate whether the cost of patenting has increased dramatically over time. That is, no study compares the cost (or even lifetime costs) of patenting in say 1980 vs. 2003 (inflation-adjusted). To study trends in patenting costs, it is necessary to repeat the same survey for different time intervals. It would then be useful to develop an index of patenting costs. Constructing such an index raises several issues: what type of patent should be used for a *standardized* comparison (i.e. page length, number of claims (dependent and independent) and drawings)? How should patent costs be deflated: using a goods or capital price index? As the estimation of patenting costs is a relatively new endeavor, it will take time before such indexes can be constructed. Until then it is difficult to know the true underlying trend in patenting costs.

It is also difficult to make cross-country comparisons of patenting costs based on the results of existing surveys. Again, there is no standard patent to hold constant across regions (in terms of length of application, depth of technology, and breadth of claims). Another factor that is not held constant is the market size of destinations. Most surveys compare the EPO, US, and Japan. But how many EPO designations would it take to make the EPO market comparable to that of the U.S. or Japan? The figure of 8.3 designations (often used) refers to the average number of designations in an EPO application, not to a "critical" market size. It would be useful to compare the costs of patenting across similar market sizes. The issue then is defining appropriate market size: should population be used, Gross Domestic Product (GDP), or per-capita GDP?

Despite the difficulties of making temporal and cross-sectional comparisons of costs, there are two senses in which patenting costs have risen recently. First, even if the cost of some "representative" patent application has been stable over time, the fact is that more such patent applications are being filed - or need to be filed. Before the increased globalization of the world economy, national filings might have been adequate for most firms. But in the current economically interdependent world, firms increasingly require and seek global patent protection. In this case, the rise in patenting costs is driven not by changes in the "price" of patenting, but by patenting needs. Secondly, it need not be the "price" of a patent application (or the fee structure) that is of concern, but the *non-price* factors that are costly or burdensome; for example, *regulations* (that require excessive paperwork and formalities, and that vary across countries), *procedures* (that involve repetitive searches and examinations, decentralized filing and payments), and *time* to process and examine patent applications.

Given these qualifications about measuring patenting costs, it is useful to discuss ways in which patenting costs in Europe could be reduced – or the process made more efficient or cost effective. A major burden in Europe is the lack of **extensive legal representation**; that is, a legal representative that can represent clients before multiple member jurisdictions. It is thus costly for applicants to hire a new local representative in each of the countries in which they seek patent protection. For the EPO, an alternative to having multiple local representatives is to provide a system of **centralized filing** for procedural tasks, such as the payment of annuities, the filing of translations, and validations. Centralized filing at the EPO removes many repetitive procedures that would otherwise have to be carried out at different national offices. Centralized filing helps reduce the risk of missing time limits to file in national offices during validation, and helps reduce agent fees.

Another major burden in the EPO is translations of patent documents. Translations play two critical roles in international patenting. First, the translated patent document must clearly disclose information to the *relevant public*. This has two purposes: first, to benefit future innovators who may build on the new inventive knowledge; and secondly, to inform third parties of the owner's legal intellectual territory. Poorly translated documents function poorly as a technology transfer device and legal document. Secondly, the translated patent application must be clear to the examiner. Poorly translated applications may lead to errors in the determination of patentability and scope.

In considering ways to reduce translation costs, it would be useful to separate price and quantity; that is, the translation fees themselves versus the amount of material to translate (or the translation needs). Some might view the fee part to be reasonable (competitively determined), while the translation requirements (due to laws and practices) to be unreasonable. Before proceeding, it is worth putting some things into perspective. First, in the EPO, patent translations are seldom considered, and even when they are, they are usually consulted many years after filing or grant. Most third parties relied on documents published in a foreign language soon after filing. Since slightly more than 70% of EPO applications were filed in English, the documents were consulted in a language most understood. The implication is that it is effectively the language of the examination that is more important to the interpretation of patent rights than the language into which the patent is finally translated. This last point is buttressed by the fact that actual deliberation before the EPO has to be in one of the three official languages (English, French, and German). Hence translations into non-official EPO languages are not needed as far as examination goes.

The original Community Patent Convention proposal was (i) to limit translation requirements to patent claims and (ii) to translate the patent specification when the patentee needed protection. (Translating in the CPC was thought to be especially burdensome because the patent has to be translated into the languages of all the Contracting State regardless of whether an applicant wishes to have protection in a particular State. By definition, the CPC patent is unitary across states: there is no concept of selective designation.) The revised 1989 CPC proposal still requires the translation of the specification, but the failure to file in a member State would result in the patent not taking effect in that state. (This creates an exception to the unitary character of the CPC patent.) Any deferred translation (till the patentee wants to enforce) must have provisions for intermediary rights, if any. The arrangement here would be that if the patentee translates within 3 months from grant, she can get *full* compensation from third parties who use the invention; if between 3 months after grant and 3 years from grant, she can get *reasonable* compensation; and if more than 3 years after grant, the prior user may continue to use the invention *without* compensating the patent holder.

Discussions of enhancing cost efficiency of the EPO should also include pricing issues. In many instances, the fees of patent offices are not commensurate with costs. The divergence of fees and costs is a major source of operational inefficiency within an organization. To the extent that fees exceed (fall short of) the costs of service, patent office services and resources would be underutilized (over utilized). The largest fees are collected at the back-end of the patent application process (post grant) while most of the costs are incurred by the patent office at the front end. As a result, the patent office does not recover costs from the unsuccessful applicants or from the roughly 40% of applicants who abandon their applications. Also, fees do not differ according to the complexity of the invention (so that applicants of more complex inventions do not pay for the greater time and resources it takes to process the applications). Likewise, applicants who create delays in the system by filing incomplete and inaccurate applications do not pay for the added costs they generate, and hence have little or no incentive to take into account the costs they impose on others through their actions. Thus a useful goal for patent offices would be to align their fees and costs; however, to do so requires that they have the cost data. To get the cost data, they would need the appropriate cost accounting system.

III. Methodology

For each potential country, the inventor compares the *benefits* and *costs* of applying for a patent in that country. The benefits depend on market size, imitation risk, and how well patent rights are protected. Given these costs and benefits, the profit-maximizing inventor's decision is to patent in a particular country if the *rise* in present value profits in that country due to patent protection exceeds the cost, else the inventor chooses to keep the invention a secret.

In order to determine the economy-wide level of patent applications, it is useful to begin with the decision-making process at the microeconomic level. Assume that there are i = 1, ..., N inventions. An inventor will seek patent protection for ith invention if the net benefit of procuring patent protection exceeds the cost of filing for protection, say:

(1) $\Delta V_i = V_i^{\text{PAT}} - V_i^{\text{NO PAT}} \geq c$

where V^{PAT} and $V^{\text{NO PAT}}$ denote the value of a firm with and without patent protection respectively, and c the cost of filing a patent. The underlying logic is that inventors have means other than patent protection to appropriate the rewards from their innovation (such as lead time, reputation, and secrecy). Thus the value of a patent right is the incremental return (ΔV) an inventor can get above and beyond that which can be realized by alternative (non-patenting) means.

Assume that all firms face the same environment (for example, market size and laws), and that the only source of heterogeneity in the economy is the *quality* of inventions. Assume for simplicity that the N inventions are in ascending order of quality; that is, invention 1 is of a lower quality than invention 2, which in turn is of a lower quality than invention 3, and so forth. Let the critical cut-off invention be the kth invention; that is, $\Delta V_k = c$ for the kth invention. Hence the first k inventions are not patented and the rest are. The quantity of patent counts is therefore:

(2) $P = (N - k) = f\,N$

where P denotes the quantity of patent applications and $f = (N - k)/N$ the fraction of N inventions that are applied for patent protection. The literature interprets f as the "propensity to patent". Patent applications increase if either the patent propensity (f) is higher (say the cutoff value of k is lower) or the overall level of inventive activity (N) is higher.

Equation (2) can be rewritten more explicitly to indicate where patent applications come from and where they go:

(3) $P_{jm} = f_{jm} N_j$

where j indexes the *source* country and m the *destination* country. Domestic patenting is, of course, the case where j = m. The issues are: what does P_{jm} depend on and what is the functional form? Typically, P_{jm} should depend on a mixture of destination and source country variables (including source-destination interaction variables (such as bilateral trade treaties)), and time effects:

(4) $P_{jm} = P_{jm}$ (source country characteristics, destination country characteristics, time effects)

Equation (4) can be estimated in two different ways: (a) at the aggregate level, where P_{jm} is the total number of patent applications from country j to country m; (b) at the sectoral level, where P_{jm} is the number of patent applications from sector s in country j to country m, where s could be defined over industrial sectors or technological fields.

IV. Data and Sample Statistics

This section discusses the data and some sample statistics. A panel data set of 16 source countries and 40 destination countries (including 14 EPO countries) was assembled for four time periods: 1985, 1990, 1995, and 2000.[2] 'Source' countries refer to the countries from which patent applications emanate and 'Destination' countries to the countries in which patent applications are filed. The list of destination countries excludes the source country itself (that is, the home market). For example, the U.S. is one of the source countries, but its list of destinations does not include itself. The reason the home market is dropped, as discussed later on, is that domestic patent applications will proxy for the total number of domestic inventions available for foreign patenting (as this information is unobservable). Also, dropping the home market helps focus attention on international patenting.

(A) Data

To implement the model discussed in the previous section, empirical measures are required of international patent flows, patent rights, patent costs, market size, and the capacity for imitation.

<u>(i) International Patenting</u>: International patenting data are from the World Intellectual Property Office's (WIPO), *Industrial Property Statistics*. The data indicate where patent applications came from and where they went. Some clarifications are in order here. A *domestic* patent application is a patent application made by a *resident* of the country. The resident need not be a *national* of that country, but say a subsidiary of a foreign multinational corporation that lists its

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[2] Turkey was dropped since it joined the EPO very recently. The data begin from 1985 because of data collection problems in the early 1980s plus the fact that member countries were relatively few.

address in that country. Likewise, a *foreign* patent application is an application by a *non-resident*, but this agent may be a national applying from an address listed abroad. These distinctions imply that stronger patent rights may attract patent applications from foreign nationals, but that the effect may show up not in foreign patent applications, but in domestic applications. Thus, it is important to interpret the results of this paper as determining how one region's characteristics (e.g. patent rights) affect patent applications from other regions, not necessarily from other nationals.[3]

<u>(ii) Patent Rights</u>: The measure of patent rights is taken from Ginarte and Park (1997) plus updates. Their study provides a rating of the *strength* -- not necessarily *quality* -- of patent rights in 110 countries for the period 1960-2000 (every five years). The index of patent rights (henceforth IPR) ranges from zero to five, with higher numbers reflecting stronger levels of protection. The value of the index is obtained by aggregating five sub-indices: extent of coverage, membership in international treaties, enforcement mechanisms, duration of protection, and provisions against loss of protection (against, for example, compulsory licensing or working requirements). These features (coverage, membership, duration, enforcement, and loss of protection) were chosen as a reference point for judging the strength of patent rights because of their adoption in international standards (for example, the *Uruguay Round* Agreements).

The numerical value of each of these sub-indices (which range from zero to one)

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[3] In practice, however, most resident patent applications are by nationals; see Patel (1995) and Ham (1999). In Ham's (1999) study of global semiconductor patenting, for example, less than 4% of *Samsung's* U.S. patents and less than 8% of *Hitachi's* U.S. patents were filed as U.S. resident patent applications, during 1975-1995.

indicates the fraction of legal features in that sub-index available in the particular country. For example, a value of 1/3 for *enforcement* indicates that a country has one-third of the possible enforcement mechanisms listed under that sub-index. A value of ½ for *duration* implies that a country grants protection for half the international standard time (of 20 years from the date of application or 17 years from the date of grant). The value for *membership in international treaties* indicates the fraction of available treaties to which the nation is a signatory. The value for *coverage* indicates the fraction of invention classes the country allows as patentable subject matter. Finally, there are several conditions or regulations under which legal authorities can revoke or reduce patent rights. The value for *provisions against loss of protection* indicates the fraction of those conditions or regulations which are not exercised in the country.[4]

<u>(iii) Patent Filing Costs</u>: Patent filing cost data were derived since international patent filing cost data are sparsely available. This paper builds on Helfgott's (1993) survey of patent filing costs. These costs include primarily translation costs, official filing fees, and agent fees. They do not include notarization charges, or taxes (e.g. stamp taxes, value-added taxes).

Helfgott's data on filing costs refer to a particular type of invention (e.g. one which allows ten claims, twenty pages of specification, two sheets of drawing, is drafted in English, and has a corporate assignee). Most importantly, the filing costs are from a U.S. applicant's point of view. The estimated filing cost of $690 (in real 1992 U.S. dollars) in Canada need not be the

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[4] Of course, actual patent protection may deviate from statutory ("laws on the books") protection. The authors investigate this possibility but find that most firms' complaints concern not so much the *execution* of laws but the *statutory differences* between industrialized countries and the *lack of laws* in less developed countries, which the index incorporates.

filing cost faced by German or Indian applicants in Canada.

To generate patent costs for more than the sample covered in Helfgott (1993), and for applicants from countries other than the U.S., an equation is first estimated that best fits the patent filing costs data in Helfgott (1993). The fitted equation is then used to predict patent filing costs for all of the required bilateral country pairs. As determinants of filing costs, geographic distance from the U.S. (and its square) and linguistic similarity with the U.S. were used. The reason is that the bulk of filing costs is due to translation. Thus, the more similar the languages between two countries, the less expensive it would be to apply for patents in each other's markets. Filing in a foreign market is also likely to be affected by geographic distance, reflecting transportation costs and perhaps differences in economic structure (regulations, customs, and practices), which may make patenting in foreign jurisdictions costly.

Based on Helfgott's original sample of 28 countries, the following regression results were obtained:

$$\widehat{\log(\text{Patent Costs})} = \underset{(7.5)}{-22.17} + \underset{(1.81)}{7.57}\log \text{Dist} - \underset{(0.11)}{0.47}*(\log \text{Dist})^2 - \underset{(0.015)}{0.032}\log \text{Ling},$$

Adj. R^2 *= 0.51, Standard Error of the Regression = 0.51*

where standard errors are in parentheses. The two variables (Distance and the Index of Linguistic Similarity) have the expected effects on patent costs, where Dist denotes "distance" and Ling "Linguistic Similarity." Distance, however, affects filing costs up to a point. Beyond that (at longer distances), inventors are likely to find ways to reduce global filing costs, such as multiple patent filings (to spread the costs of filing among several destinations) or (if a transnational corporation) establish a corporate patenting branch in a foreign office. The simple correlation between actual costs and predicted costs is 0.64.

With the above fitted equation, patent costs between any pair of source and destination countries can be generated, as distance and linguistic similarity data are widely available.[5] The data thereby generated are the measure of patent filing costs. To maintain consistency (in the way patent filing costs are measured), the original data in Helfgott (1993) are replaced with the generated data.[6]

The generated costs are in real 1992 U.S. dollars. To obtain time-series estimates of patent filing costs for 1975, 1980, 1985, and 1990, the GDP deflator (where 1992=100) was used for each country to infer the filing costs for those years in real 1992 U.S. dollars.[7] For example, if the 1975 deflator = 50, the 1975 filing cost figure was considered to be half the 1992 estimate. This approach, however, assumes no "real" changes in filing costs. To allow for them, the cost figures were adjusted upward by the real GDP per capita growth rates (that is, each cost figure was multiplied by one plus the destination's real GDP per capita growth rate in that period). The working assumption here is that the growth in demand for patenting resources (and consequent rise in real filing costs) parallels the growth in market size.

(iv) Market Size and Hazard of Imitation: Per capita GDP (in real 1992 PPP adjusted U.S.

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[5] Data on distance and linguistic similarity are from Boisso and Ferrantino (1996).

[6] In addition, some of the countries in Helfgott (1993) are not among the destination countries considered in this paper, so that the original patent cost data could not be used in the empirical analysis. However, as Figure 1 shows, the original and derived data are quite aligned. The simple correlation is 0.75.

[7] Deflator data are from Summers et. al. (1995)

dollars) is used as a measure of the market size of patent destinations.[8] The number of scientists and engineers per 10,000 workers is used as a crude measure of the capacity of a country to imitate.[9]

(B) Sample Statistics

Table 1 presents some sample statistics. The U.S. and Japan are included in the study for purposes of comparison. The first column reports the level of per capita GDP, the second the level of patent rights, the third the ratio of scientists and engineers to the labor force, and the fourth the cost of filing patents in that country. The fifth column shows foreign patenting from the destination's perspective, indicating the average number of foreign patent applications received. The U.S. is the major recipient of foreign patent applications, receiving nearly 50,000 per year during the sample period. In general, countries that are richer, have stronger patent rights, higher shares of scientists and engineers in the workforce, and lower patent filing costs, tend to attract more foreign patent applications.

The higher income nations tend to face lower patent filing costs amongst one another. Recall that costs depend on linguistic similarity and distance. Thus costs of filing are lower when these nations file patents in each other's markets because they tend to be "close" in economic as well as geographic distance, and tend to have lower translation costs amongst one

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[8] GDP, population, and exchange rate data are taken from Summers et. al. (1995).

[9] Data on scientists and engineers are from UNESCO *Statistical Yearbook* (various issues).

another. The richer economies tend also to have higher levels of IPR and to be well endowed with scientists and engineers (S&E). This is either because countries that protect patent rights strongly tend to stimulate research, human capital accumulation, and productivity, or because countries that are more industrialized and have more S&E tend to have the greater incentive to provide patent protection.

The sample correlations in Table 1 show that a destination's per capita GDP, index of patent rights (IPR), share of scientists and engineers in the workforce (S&E), and quantity of foreign patents are all positively related, and they in turn are negatively correlated with patent costs (PCOST). The next section examines the extent to which these destination factors explain source country patenting.

V. Empirical Results

This section estimates the relationship between patenting propensity and its determinants, as hypothesized in equation (4). The fundamentals discussed, however, are not the only source of variation across countries. Unobserved heterogeneity across destinations is likely to exist due to cross-country differences in legal institutions and practices, or in the experiences of patent attorneys in filing patents. Moreover, heterogeneity across source countries is also likely to exist due to differences in the *quality* of their inventions. Source country heterogeneities, of course, do not vary across destinations, but matter between source countries.

An additive error term in equation (4) is motivated by the fact that some profitable inventions fail to be patented, while some unprofitable ones are patented. The error term could also be influenced by specific *destination* and *source* country effects. The destination effects may be either fixed or stochastic. The source country effects may be reflected in the intercept, error term, or in the slopes. Hence, in what follows, two types of samples are considered. The first is a pooled sample (where all sources countries are pooled) in which the source country heterogeneities are reflected in “intercept” dummies. The second type splits the sample by individual source countries in which source country heterogeneities can be reflected in the coefficient estimates (“slopes”). Moreover, as will be explained later, the individual source country sample allows for an interdependent (cross-source country) error structure.

The regressors for equation (4) are the destination’s market size (as proxied by GDP per capita, GDPC), the index of patent rights (IPR), share of scientists and engineers in the workforce (S&E), and cost of filing patents (PCOST). A European Patent Office (EPO) dummy is also included, which equals 1 if the destination country belongs to the EPO. An EPO destination is attractive to the extent that it is easier, by design, to add an extra designation to a European patent application than to make a separate application to another state. There may also be time effects (due to technological progress or globalization) that influence trends in foreign patenting. Hence, a time trend (TIME) is also included as a regressor.

It is convenient to log these variables (except for TIME and EPO) because there exist large variations in the propensity to patent. The qualitative results are the same whether or not the variables are logged. In addition, all errors are White-corrected for heteroskedasticity across destinations.

The empirical results are in Tables 2 - 4. Table 2 presents estimates of equation (4) for the aggregate (pooled) sample and Table 3 for the disaggregated source-country by source-country sample. Table 4 reports on the results of a nonlinear specification *test* - namely on whether an inverted-U relationship exists between F_{jn} and patent rights. At issue is whether given sufficiently strong market power in market n, inventors have less incentive to bring new inventions to the region.

(A) Pooled Sample

Table 2 presents the panel data estimates for the aggregate sample. The estimation includes intercept dummies for source countries (the coefficients of which are not reported in Table 2 to conserve space).

The regressors all have the expected signs and are statistically significant at conventional levels -- except for the ratio of scientists and engineers to the workforce (which has a significance level exceeding 5%). The results also show the advantage of applying in EPO destinations. Controlling for EPO destinations causes the coefficient estimates of IPR to be lower. The coefficient estimate of log IPR in all cases is greater than one, indicating a highly elastic response; that is, a 1% increase in the level of patent rights, holding everything else constant, raises the rate of foreign patenting by more than 1%. However, it would not be proper to interpret this as a type of increasing return since in order to determine the "return," information is needed on what it costs to strengthen patent rights by 1% and on the benefits from foreign patents.

An F-test rejects the null of no individual effects and a χ^2-test finds the random effects estimates (RE) not to be consistent (the individual effects indeed are correlated with the RHS variables). There are likely to be a number of omitted destination factors that are important to the foreign patenting decision and that correlate with the market size and level of development of nations (factors such as political rights, property rights in general, and level of institutional development (particularly of their patent offices and administration)). There is also a high degree of serial correlation in the residuals, which is consistent with the omission of important variables.

Thus the rest of this paper focuses on the fixed effects (FE) estimates. It is interesting to note how closely the coefficients on the market size variable are to unity. With the EPO effect controlled for, the FE estimate of the coefficient on log GDPC is 1.277. Schmookler (1966) earlier found evidence supporting the idea that patenting is *unit elastic* with respect to market size; that is, a given percentage expansion in the market drives an equivalent expansion in patenting activity (which shows how closely inventive activity is driven by the market for the use of inventive output). A formal F test (using the FE estimates), however, rejects the hypothesis that the coefficient is unity. The F-statistic with one restriction is F(1,2554) = 7.29, whose p value is 0.0073. The difference in result is likely due to the fact that Schmookler focused on U.S. firms and industries and that his dependent variable was in levels (i.e. total patents), not in fractions or ratios. But it is remarkable how closely the coefficients here (and in the individual country samples) are to unity..

(B) Country by Country Sample

Here equation (4) is estimated separately for select individual source countries.

However, the individual source country equations are estimated as a *system of equations*. The reason is that the disturbances in the foreign patenting equations are correlated due to 'shocks' that are common to source countries -- shocks such as international political and economic events, government policies, and increases in knowledge capital. For instance, new basic knowledge may spread worldwide (via international spillovers or transactions) and influence invention and patenting activities across countries. There is also some interdependence among source countries in filing applications worldwide. International patent applications compete for scarce resources (used in searching and examining patents) so that one country's patenting in a destination affects another country's patenting in that same region. For these reasons, it is necessary to account for correlations among source country residuals. Indeed, there exists a high correlation among residuals from OLS country by country estimates (the same is true of fixed effects and random effects residuals). The null hypothesis that the matrix of source equation residuals is diagonal can easily be rejected (the Lagrange multiplier test statistic is 2416.8). While quite large, the system can be readily estimated by a conventional seemingly unrelated regression (SUR).[10]

As there does exist significant individual (or destination) effects, as shown earlier, the SUR is combined with a fixed effects estimation (FE). In practical terms, this means that all the variables were demeaned by destination unit. The transformed dependent variable and regressors were substituted into the system of equations and the system then estimated by SUR (without constant terms).

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[10] Note that the equations do not have identical explanatory variables, since the source country itself is dropped from the list of destination countries and since patent filing costs

The results in Table 3 show how source countries vary in their sensitivity to destination factors. Foreign patenting by the U.S. and Germany is highly elastic with respect to the destination's IPR (the coefficients of log IPR exceed 3), while that of Spain and Sweden is less elastic. Patent rights, however, matter importantly to all source countries.

As for the other regressors, GDP per capita has a significantly positive influence, except only moderately to Switzerland. The proxy for imitative capacity is not an important determinant of foreign patenting by France, Germany, Japan, Netherlands, Spain, Sweden, Switzerland, UK, and USA.[11] The coefficients for patent filing costs are significantly negative for *all* the source countries. The EPO dummy is not especially significant at this country level; the variable exhibits little variability within source country samples. The "EPO factor" matters primarily in explaining between-source country patenting behavior (in the pooled sample). The individual country sample also reveals why the time trend is insignificant in the aggregate (pooled) sample; for some countries the coefficient of TIME is negative and for others it is positive, so that in the aggregate the influences of TIME cancel out.

To summarize, patent rights, patent filing costs, and market size have in general the *expected* effect on international patenting. The serial correlation has been eliminated for all source countries, but a significant amount of unexplained variance exists. Just 20-40% of the variation in the data is explained by the model; the remainder is due to unobserved destination fixed effects. Thus, what seemed intuitive (for example, that patent rights would positively influence international patenting) is empirically correct, but only a small proportion of the data is

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depend on the particular bilateral pairing of source and destination countries.

[11] This could mean either that the capacity to imitate is not a significant determinant of

accounted for by such factors.

(C) Test of Nonlinear Relationship between IPR, Market Size, and Patenting

Table 4 reports on whether patent protection has an inverted-U relationship with foreign patenting. This may arise if excessive patent protection or market power induces inventors to reduce their patenting abroad. The reason is that increased market power reduces the elasticity of demand facing foreign inventors.[12] To determine whether at some point the market power effects dominate, the model was expanded to include quadratic terms - namely the square of the log of the patent rights index. The first half of Table 4 shows the results for the aggregate sample and the second half summarizes for the individual country sample just the sign of the coefficient estimates of the quadratic terms and indicates whether they were significant at conventional levels. For the pooled sample, the coefficient of the quadratic term is significantly positive, indicating that increases in the level of patent rights have a positive and *increasing* effect on foreign patenting. This is not consistent with the inverted-U hypothesis. For the individual country samples, in no case is there a significant positive sign on log (IPR) and significant negative sign on its square; that is, no sign of an inverted-U relationship. Also a likelihood ratio test (for the system estimation as a whole) cannot reject the null that the coefficients of all the quadratic terms should be jointly zero.

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foreign patenting, or that log S&E is a poor proxy for the capacity to imitate for these countries.

[12] See also Maskus and Penubarti (1995) for a discussion of the *market expansion effect*

VI. Tentative Conclusions

As mentioned above, very little empirical work exists on the determinants of patenting and innovation in Europe or elsewhere. Previous research has largely been on economic conditions (for example, market size, trade relations, and productivity of firms). The central focus of this study is to provide a more concrete sense of how patent policies and regimes contribute to innovative activity and technology diffusion in Europe (by nationals and by foreigners).

The results in this paper show that patent rights are a positive influence on technology diffusion within the European area. While the qualitative and quantitative effects of patent rights vary across source countries, the estimates generally indicate quite an elastic response of foreign patenting to patent rights - that is, a given strengthening of patent rights in a destination country (by 1%), holding everything else constant, tends to stimulate foreign patenting more than proportionately (by more than 1%). The positive influence of patent rights on foreign patenting was not found to taper off as patent rights reach very strong levels. For instance, the data do not suggest any inverted U-relationship between foreign patenting rates and patent rights, which would arise if patent protection at high levels granted excessive market power to inventors and induced them to restrict their patenting.

The paper also finds that patenting costs matter. The elasticity of demand for patents is found to vary (being inelastic in some regions and elastic in others). The "mean" effect appears to be close to unit-elastic. The elasticity of demand (with respect to fees) has implications for

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and *market power effect* of patent protection.

patent office revenues and the revenues of patent practitioners. More importantly, for innovators, the sensitivity of patenting to cost indicates the possibility that costs can be an entry barrier for innovators, particularly small-medium enterprises. In this case, the patent regime discriminates in favor of large, incumbents (who can more afford to use the system).

The next step in the research project is to endogenize R&D and innovation activities – to show how patent rights and costs affect the decision to invest in research and development. It is from these investments in R&D that future patentable inventions are derived. The paper thus far has focused on the diffusion of ideas; thus the next step is to explore the determinants of patentable ideas.

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Table 1. Sample Statistics (Average 1985-'00)

	GDPC	IPR	S&E	PCOST	Foreign Patents
Austria	10818	3.83	20.74	1661	20799
Bel	12740	3.16	45.14	1961	5291
Den	12114	3.52	29.03	1726	12484
Fin	11643	2.75	38.94	2000	4791
Fra	12041	3.74	37.84	1551	38145
Ger	12223	3.59	48.56	1452	38460
Italy	10475	3.82	25.17	1525	27807
Japan	11139	3.86	70.07	1872	28513
Neth	11527	4.05	54.11	1652	25674
Swe	13157	3.41	46.21	2066	23337
Swit	14665	3.64	50.03	1527	22731
UK	10983	3.44	31.81	1483	43330
USA	15900	4.27	65.91	1955	49224
Greece	6024	2.43	6.87	2721	5088
Ire	7295	2.99	25.81	1707	2694
Spain	7937	3.37	14.81	2049	16491

Definitions and Variable Names:

GDPC - GDP per capita in real U.S. PPP 1992 dollars
IPR - index of Patent Rights
S&E - number of scientists and engineers per 10,000 workers
PCOST - patent filing cost in real U.S. PPP 1992 dollars
FOREIGN PATENTS - total foreign patents received per year from the source countries

Correlation Matrix

	GDPC	IPR	S&E	PCOST	Foreign Patents
GDPC	1				
IPR	0.611	1			
S&E	0.719	0.612	1		
PCOST	-0.209	-0.255	-0.097	1	
Foreign Patents	0.698	0.658	0.532	-0.118	1

Table 2. Aggregate Estimates

Dependent variable is log(F)

	No EPO Effect			*With EPO Effect*		
	OLS	FE	RE	OLS	FE	RE
Constant	-10.3 (0.67)	--	-11.7 (0.73)	-8.77 (0.66)	--	-10.9 (0.73)
log GDPC	0.718 (0.068)	1.262 (0.145)	0.909 (0.075)	0.543 (0.066)	1.277 (0.144)	0.862 (0.074)
log S&E	0.252 (0.049)	0.149 (0.077)	0.150 (0.052)	0.312 (0.046)	0.144 (0.076)	0.169 (0.051)
log IPR	2.161 (0.099)	2.478 (0.209)	2.289 (0.132)	1.679 (0.105)	2.058 (0.229)	1.928 (0.139)
log PCOST	-0.427 (0.049)	-0.477 (0.078)	-0.442 (0.056)	-0.398 (0.047)	-0.494 (0.077)	-0.469 (0.055)
Time	0.049 (0.028)	0.026 (0.025)	0.048 (0.017)	-0.024 (0.029)	0.014 (0.026)	0.029 (0.017)
EPO	--	--	--	1.151 (0.072)	0.304 (0.073)	0.465 (0.069)
Adj R^2	0.64	0.92	0.63	0.66	0.92	0.65
F-test	14.16			13.11		
χ^2-test			15.6			23.9
DW	0.223	1.298	0.222	0.270	1.305	0.235

Notes: F is patent applications in country n per home country patents. See Table 1 for other variable definitions. Heteroskedastic-consistent standard errors are in parentheses. DW is the Durbin-Watson statistic, F-test the statistic for testing the null of common intercepts (or of no individual effects), and χ^2-test the statistic for testing the null of no correlation between the individual effects and other regressors. The *EPO Effect* refers to advantages of filing in European Patent Office destinations. EPO = 1 if the destination is an EPO member. Source country dummies were included (but their effects are not reported for reasons of space).

Table 3. System of Individual Countries

Seemingly Unrelated Regression (SUR) and Fixed Effects (FE) Estimation

	log GDPC	log S&E	log IPR	log PCost	Time	EPO	DW	Adj R-sq
Aus	0.854	0.425	2.785	-1.122	0.789	0.098	1.82	0.33
	(0.447)	(0.238)	(0.888)	(0.224)	(0.169)	(0.105)		
Bel	1.517	0.545	3.668	-1.057	0.023	0.055	2.004	0.28
	(0.358)	(0.181)	(0.485)	(0.213)	(0.169)	(0.098)		
Den	0.806	0.573	2.439	-1.234	0.275	0.007	1.89	0.21
	(0.379)	(0.222)	(0.703)	(0.179)	(0.157)	(0.073)		
Fra	1.038	0.202	2.358	-1.014	0.204	0.068	2.37	0.25
	(0.355)	(0.184)	(0.501)	(0.191)	(0.149)	(0.07)		
Ger	1.433	-0.128	3.466	-1.073	-0.201	0.044	2.03	0.34
	(0.459)	(0.271)	(0.639)	(0.196)	(0.161)	(0.079)		
Jpn	1.579	-0.106	3.774	-0.982	-0.209	0.142	2.13	0.25
	(0.488)	(0.272)	(0.695)	(0.196)	(0.165)	(0.107)		
Neth	1.020	-0.243	2.106	-1.217	0.019	0.078	2.16	0.22
	(0.452)	(0.298)	(0.598)	(0.174)	(0.145)	(0.085)		
Spain	0.991	0.073	1.816	-0.790	0.167	0.041	2.07	0.18
	(0.400)	(0.258)	(0.534)	(0.179)	(0.136)	(0.081)		
Swe	0.919	0.062	1.582	-0.999	0.801	0.009	2.005	0.32
	(0.349)	(0.244)	(0.641)	(0.202)	(0.163)	(0.071)		
Swit	0.700	-0.237	2.799	-1.012	0.516	0.021	2.38	0.22
	(0.443)	(0.284)	(0.553)	(0.189)	(0.129)	(0.063)		
UK	1.343	0.046	2.722	-0.665	0.205	0.111	2.07	0.26
	(0.330)	(0.243)	(0.572)	(0.176)	(0.119)	(0.080)		
USA	1.531	-0.189	3.126	-1.205	0.416	0.106	1.77	0.29
	(0.441)	(0.269)	(0.623)	(0.217)	(0.132)	(0.084)		

Notes:
See Previous tables for variable definitions
Heteroskedastic-consistent standard errors in parentheses.
Fixed Effects Controlled for by demeaning each variable (by destination unit) prior to SUR

Table 4. Test of Nonlinear Specification

I) Pooled Countries - Fixed Effects Estimation

$$\log F = \underset{(0.141)}{1.21} \log GDPC + \underset{(0.075)}{0.122} \log S\&E - \underset{(0.386)}{0.076} \log IPR - \underset{(0.077)}{0.526} \log PCOST - \underset{(0.026)}{0.006}\, Time$$

$$+ \underset{(0.084)}{0.086}\, EPO + \underset{(0.279)}{1.53} (\log IPR)^2, \qquad \text{Adj } R\text{-sq} = 0.92,$$

Heteroskedastic-consistent standard errors are in parentheses.

II) Individual Countries - Fixed Effects & SUR Estimation

Signs of Coefficient of:

	log IPR	$(\log IPR)^2$
AUS	-*	+*
BEL	+	+*
DEN	-	+*
FRA	-*	+*
GER	-	+*
JPN	-	+*
NETH	-	+*
SPA	-	+*
SWE	+	+
SWIT	+*	+
UK	+	+*
USA	-	+*

where * indicates significant at conventional levels (i.e. p-value < 0.05).